

## Sacramento River Temperature Management Planning

NMFS' 2009 Biological Opinion to Reclamation for the long-term operations of the Central Valley Project (CVP) and State Water Project (SWP) (CVP/SWP operations BiOp) requires Reclamation to operate Shasta Reservoir in a manner that provides suitable water temperatures from mid-May through October to support spawning and egg incubation of winter-run Chinook salmon and spring-run Chinook salmon in the upper Sacramento River. As air temperatures rise in the summer, water temperatures below Shasta and Keswick (Keswick Reservoir is the reregulating reservoir for Shasta Reservoir) dams are managed through scheduled releases of a limited amount of cold water from the depths of Shasta Reservoir, known as the cold water pool.

Temperature management planning for the Sacramento River can be framed into three relatively discrete seasonal efforts:

- *February forecast:* Reclamation typically issues initial allocations of deliverable water to north-of-Delta and south-of-Delta contractors in late-February. Prior to issuing those initial allocations, Reclamation issues to NMFS a “February forecast” of operations, including forecasted water temperatures in the upper Sacramento from mid-May through October, based on an estimate of precipitation and runoff within the Sacramento River basin at least as conservative as the 90 percent probability of exceedance (90% chance that the hydrology would be wetter than modeled). NMFS reviews the draft February forecast to determine whether the predicted delivery schedule is likely to leave sufficient water for temperature management to meet ESA requirements, and provides a written evaluation to Reclamation prior to Reclamation making its initial allocation announcements.
- *Summer temperature management:* The “February forecast” kicks off development of the temperature management plan (TMP), which allows Reclamation, in consultation with NMFS, to achieve optimal cold water management in a given year for holding, spawning, and egg incubation of ESA-listed winter-run Chinook salmon (peak spawning in July) and spring-run Chinook salmon (peak spawning in September and October) in the Sacramento River between Keswick Dam and Bend Bridge (see map in Figure 1), while retaining sufficient carryover storage to manage for next year’s cohorts.

NMFS and Reclamation continue coordination on development of the summertime Temperature Management Plan (TMP) throughout the spring, based on updated monthly 50 percent and 90 percent exceedance forecasts and temperature modeling results, including projected End-of September (EOS) storage in Shasta Reservoir. Developing multiple options for temperature management allows for meaningful discussion of appropriate risk management strategies in a given year, based on timely hydrologic and biological considerations. Important factors differ from year to year, and include: the projected size of the winter-run year class and the extent of habitat needed; timing of spawning and location of redds based on aerial surveys; the extent of the cold water pool; forecasted air temperatures; and operation of the temperature control device to provide optimal use of the cold water pool.

The final TMP is submitted to the State Water Resources Control Board, pursuant to Water Rights Order 90-5<sup>1</sup>, in mid-May and is implemented by Reclamation in coordination with NMFS and the Sacramento River Temperature Task Group (SRTTG). The SRTTG can refine the TMP based real-time information, including run timing, location of redds, air and surface water temperature modeling, and projected versus actual extent of the cold water pool.

The temperature criterion in the 2009 NMFS BiOp is that daily average water temperature shall not exceed 56°F between Balls Ferry and Bend Bridge. Because most winter-run Chinook salmon spawning occurs upstream of Clear Creek's confluence with the Sacramento River, and because of recent data suggesting that cooler water temperatures may improve egg survival (see “ADAPTIVE MANAGEMENT, Temperature Compliance Location and Value” section, below), in recent years, Reclamation and NMFS have implemented pilot studies to target cooler water temperatures considerably further upstream at the location of the winter-run redds.

- *Fall storage/conservation:* Reclamation must develop and implement a Keswick release schedule for November through February. The release schedule depends on EOS carryover storage and hydrology, and could include reduced deliveries and exports. Other considerations include the need for flood control space; the need for stable Sacramento River level/stage to increase habitat for optimal spring-run and fall-run redds/egg incubation and minimization of redd dewatering and juvenile stranding; and the potential to implement the U.S. Fish and Wildlife Service’s Delta smelt RPA salinity/flow action (called the Fall X2 action).

## **ADAPTIVE MANAGEMENT**

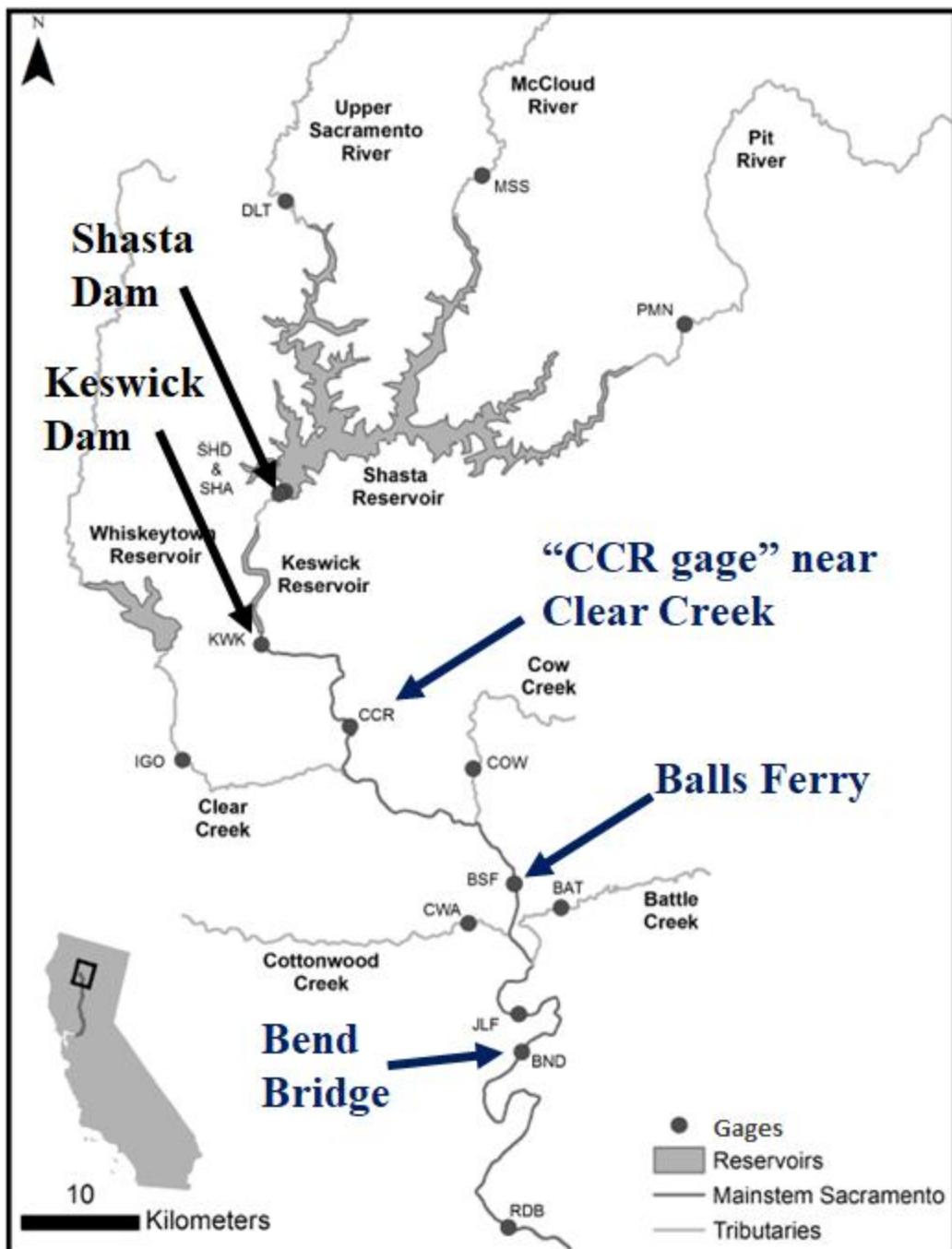
Since issuance of the NMFS BiOp, Reclamation, in consultation with NMFS and the SRTTG, have implemented various adaptive management strategies in response to real-time conditions of winter-run Chinook salmon:

### Temperature Compliance Location and Value

The loss of two cohorts of wild winter-run production during the drought in 2014 and 2015 highlighted the challenges of the current RPA implementation and effectiveness, and led to reinitiation of consultation in 2016. As part of the reinitiation process, NMFS and Reclamation have continued to advance science and modeling and have followed recommendations from the independent science review panel to conduct operational studies to manage temperatures over the redds at Clear Creek, as opposed to further downstream between Balls Ferry and Bend Bridge. This approach is intended to save water and be more effective at protecting salmon eggs and emergent fry from temperature effects.

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<sup>1</sup> The State Water Resources Control Board’s Order 90-5 establishes water right requirements on the Reclamation’s operations of Keswick Dam, Shasta Dam, the Spring Creek Power Plant and the Trinity River Division related to temperature control in the Upper Sacramento River for the protection of fishery resources.



**Figure 1:** Map of Shasta Reservoir and Keswick Reservoir and the upper Sacramento River (adapted from Figure 1 in Daniels et al. 2018<sup>2</sup>).

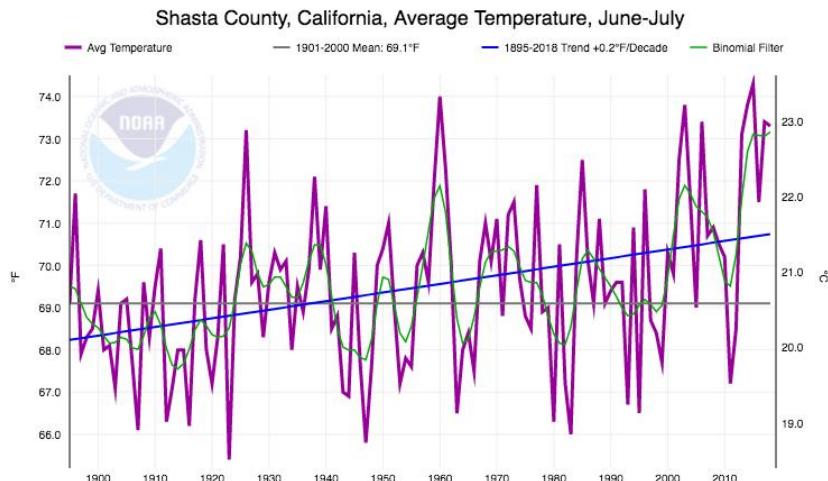
<sup>2</sup> Daniels, Miles E., Vamsi K. Sridharan, Sara N. John, and Eric M. Danner. 2018. Calibration and validation of linked water temperature models for the Shasta Reservoir and the Sacramento River from 2000 to 2015. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-SWFSC-597. <https://doi.org/10.7289/V5/TM-SWFSC-597>

The literature on temperature effects points to 48°F being optimal for egg incubation. In 2017, Reclamation managed to 53°F over the redds with positive results on survival. In 2018, Reclamation is managing to 53.5°F over the redds, and effects on survival will be calculated in January. Reclamation and NMFS have also developed new tools to support decision-making, and a draft science and adaptive management plan that is now being discussed with water districts and NGOs as part of a new collaborative science effort for the Sacramento River.

Winter-Run Redd Dewatering and Juvenile Stranding: The typical hydrograph below a dam is highest flows during the summer, and lowest flows in the winter, which is the reverse of a natural hydrograph. For the Sacramento River, this is the result of providing for Delta export and outflow needs, diversions along the Sacramento River, and temperature management for winter-run. However, depending on location, the redds constructed by winter-run that spawn during peak Keswick Dam releases may be vulnerable to dewatering in the fall as Keswick Dam releases are reduced. In the fall, Reclamation consults, primarily with NMFS and the California Department of Fish and Wildlife, prior to Keswick Dam release reductions, to ensure that winter-run redds are not dewatered.

Data Set Used for Temperature Modeling: In the past, Reclamation used average historical air temperatures to input into their 90 percent exceedance forecasts and temperature modeling. However, the recent decade or so have produced some of the hottest summers, driest water years, wettest months, most days over 100°F, etc., so that the temperature model runs do not reflect conservative estimates. Over the last four or so years, Reclamation has utilized air temperature data sets that include the above-mentioned extremes in order to generate conservative temperature model runs.

Figure 2 shows air temperature trends in Shasta County since 1895. As shown in the graph, there is a trend of increasing June-July air temperatures. With warming trends in air temperatures, new challenges will arise with water temperature management in the Sacramento River.



**Figure 2:** Air temperature trends in Shasta County. Year is on the X-axis, and temperature is on the Y-axis. The purple line shows average air temperature in June and July annually from 1895 to 2018. The gray line is the mean of all June-July temperatures from 1901 through 2000. The blue line represents a simple linear fit to the air temperature data.